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DEVICE FOR SUPPLYING AIR TO FUEL CELLS

[0001] The present invention relates to a device for supplying air to fuel cells as defined in more detail in the preamble of Claim 1.

[0002] A device according to the definition of the species for supplying air to fuel cells is known from DE 197 55 116 C1. Air is supplied to the fuel cell via a compressor and is subsequently expanded in an expander. The expander is operated by the exhaust air of a catalytic burner which is also situated downstream from the fuel cell.

[0003] Frequently problematic in these known air supply units is the fact that the fuel cell cannot be supplied with enough air and that, in addition, the compressors and the expanders have low efficiencies.

[0004] A pump for generating pressure or partial vacuum is known from WO 00/57062 A1.

[0005] The object of the present invention is to provide a device for supplying air to fuel cells which has a simple design and operates effectively.

[0006] According to the present invention, this object is achieved by the features recited in Claim 1.

[0007] The compressors and expanders of the device according to the present invention for supplying air to fuel cells, which are designed according to the present invention as claw compressors and claw expanders having compressor wheels and expander wheels, enable very high compression ratios and thus a very good fresh air supply to the fuel cell. At the same time, they have a simple design and function reliably.

[0008] Advantageous embodiments and refinements of the present invention arise from the subclaims as well as from the exemplary embodiment schematically illustrated in the drawing

below.

[0009] Figure 1 shows a fuel cell having a device according to the present invention for supplying air;

[0010] Figure 2 shows a section through the device according to the present invention for supplying air;

[0011] Figure 3 shows an enlarged representation of a unit including a compressor and an expander, and

[0012] Figure 4 shows the mode of operation of the compressor of the device according to the present invention;

[0013] Figure 5 shows a diagram in which the torque of the compressor and the expander is plotted against the rotation angle.

[0014] Figure 1 shows a highly schematic representation of a fuel cell 1 which, in a manner known per se, has a cathode chamber 2 and an anode chamber 3. A hydrogen-containing gas is supplied to anode chamber 3 in a manner known per se but not illustrated, however. Air or air oxygen is supplied to cathode chamber 2, a device 4 for supplying air to fuel cell 1, described in detail below, being provided for this purpose.

[0015] Device 4 has a compressor 5 situated upstream from fuel cell 1 and an expander 6 situated downstream from fuel cell 1. The type of connection of compressor 5 and expander 6 to fuel cell 1 is not explicitly shown; it may, however, be established via standard lines.

[0016] As is also apparent in Figure 1, compressor 5 is designed as a claw compressor and has two compressor wheels 7, 7' which in turn each have two compressor claws 8, 8'. Expander 6 is in principle identical to compressor 5 and has two expander wheels 9, 9' which in turn have expander claws 10, 10'. Due to the rotation of compressor wheels 7, 7', the gas, arriving at

compressor 5 at an inlet 11, is taken in at a pressure P_1 and compressed to a pressure P_2 prevailing at an outlet 12, which is later explained in greater detail. The gas is supplied to fuel cell 1 using pressure P_2. A pressure P_3 at which the gas is supplied to expander 6 at an inlet 13 of the expander prevails in the gas downstream from fuel cell 1. Due to the rotation of expander wheels 9, the gas is expanded to a pressure P_4 which prevails at an outlet 14 of expander 6.

[0017] The arrows denoted with the letter "A" indicate the respective rotational direction of compressor wheels 7, 7' and expander wheels 9, 9'. It is thus apparent that compressor 5 and expander 6 have the same rotational direction. However, in order to achieve compression from pressure P_1 to pressure P_2 in compressor 5 and an expansion from pressure P_3 to pressure P_4 in expander 6, compressor 5 and expander 6 have a mirror-inverted configuration.

[0018] Pressure ratios P_2/P_1 and P_3/P_4 are predefined in the present case by the geometry of compressor wheels 7, 7' and expander wheels 9, 9', i.e., by the design of compressor 5 and expander 6; they may, however, also be adjustable via a mechanism (not shown).

[0019] As is apparent in Figure 2, compressor wheels 7, 7' and expander wheels 9, 9' are mounted on common shafts 15, 15'. Shaft 15 as well as shaft 15' are mounted via two bearing elements 16 and 17 and 16'and 17'. In addition, common shafts 15 and 15'are connected by a synchronizing gear unit 18 which ensures a synchronous run of compressor wheel 7 with compressor wheel 7' and expander wheel 9 with expander wheel 9'. Shaft 15 is connected to a drive motor 19 which drives device 4.

[0020] In the described device 4, which represents a combination of compressor 5 and expander 6, the gas compressed in compressor 5 is supplied to expander 6 where residual energy is extracted from the gas via expansion. Due to the common mount, expander 6 supplies the reclaimed power directly to the two shafts 15 and 15', thereby reducing the power of drive motor 19 required for compressor 5.

[0021] As is apparent in Figure 3, compressor 5 and expander 6 are cooled via expansion cooling. As is apparent in Figure 2, the cooler expander 6 is situated on the side of synchronizing

gear unit 18. Moreover, after exiting expander 6, the gas is used for cooling compressor 5 as well as attached bearing elements 16 and 16'. To achieve this, compressor 5 and expander 6 are situated in a common housing 20 which has a double wall.

[0022] Figure 4 shows the operating principle of compressor 5 in a total of six steps. In step a), due to the rotation of compressor wheels 7, 7' according to arrow A, the volume of a pumping chamber 21 situated in the area of inlet 11 is increased and the gas is taken in via inlet 11 also referred to as intake channel. Step b) shows a pumping chamber 21 enlarged by the rotation.

[0023] The separation of the delivery volumes of the two compressor wheels 7, 7' results in an isochoric transport of the gas toward the pressure side, i.e., outlet 12. Step d) shows the combination of the two volumes which is associated with compression. However, the gas cannot exit compressor 5 since lower compressor wheel 7' seals outlet 12. Only when outlet 12 is opened, as is shown in step e), is the pre-compressed gas able to be pushed out, as is shown in step f). In this way, the gas is compressed from pressure P_1 to pressure P_2 and transported toward fuel cell 1.

[0024] It is apparent in Figure 2 that compressor wheels 7, 7' are substantially wider than expander wheels 9, 9'. Therefore, the pumping chamber of expander 6 (not shown) is smaller than the corresponding pumping chamber 21 of compressor 5. The size of the pumping chamber of expander 6 is generally 0.3 to 0.6 times the size of pumping chamber 21 of compressor 5.

[0025] Relatively simple manufacturing methods may be used for manufacturing compressor wheels 7, 7'and expander wheels 9, 9', since, in contrast to helical compressors, for example, the geometry of compressor wheels 7, 7' and expander wheels 9, 9' is not twisted in the axial direction. Since the compression, as described above, takes place radially rather than in the axial direction, the length or width of compressor wheels 7, 7' and expander wheels 9, 9' is smaller than their diameter so that a compact design may be implemented, in particular when compressors and expanders have a multi-stage design. Such a multi-stage design may be utilized to implement greater pressure differences or to achieve independent volume flows under

different individual pressures.

[0026] Figure 5 shows a torque characteristic of compressor 5 and expander 6 plotted against the rotation angle of compressor wheels 7, 7' and expander wheels 9, 9'. Since compressor 5 compresses in the rotational direction while expander 6 expands in the rotational direction and since, as described above, the lengths of compressor wheels 7, 7' and expander wheels 9, 9' are different, the illustrated torque characteristics result. Expander 6 is initially in-phase with compressor 5, which makes it possible, via a suitable angular shift, to reduce the difference between the maximum torque and the minimum torque by approximately 20%.